# Rice monitoring in Taiwan

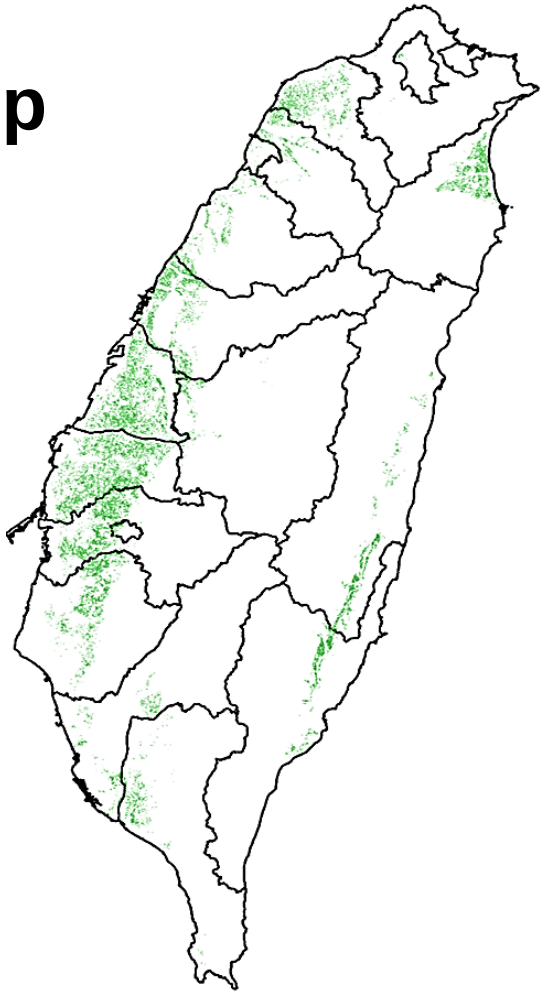
**N.T. Son, C.F. Chen, C.R. Chen,**
**W.H. Tseng, S.H. Chen**

**Center for Space and Remote Sensing Research National Central University**
**Jhongli, Taoyuan City, TAIWAN**

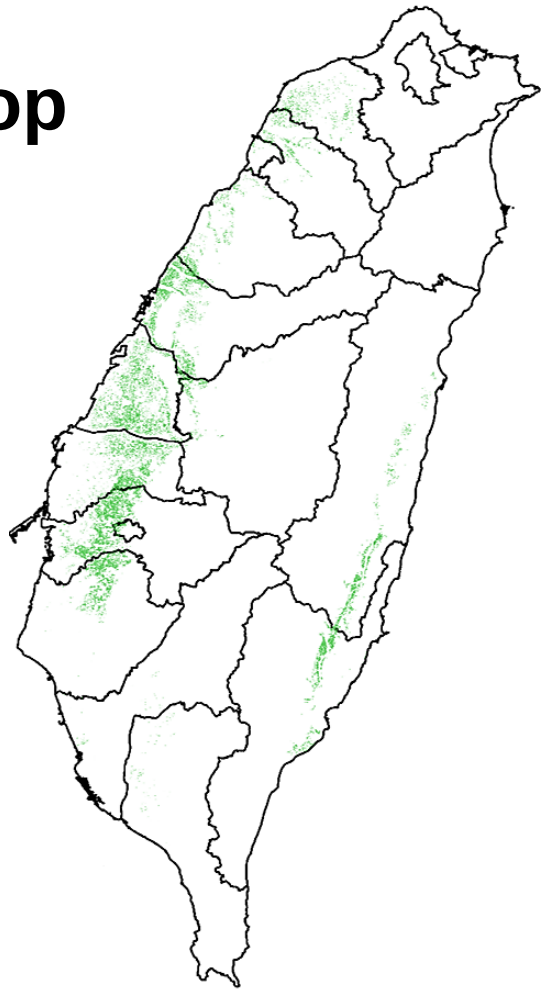
**Tel.: 886-0933012400**
**E-mail: ntson@csrsr.ncu.edu.tw**

# Introduction

1st crop



2nd crop



- **Rice is the most important food crop in Taiwan, accounting for approximately 7.5% (2,703 km$^2$) of the total land area.**

# Introduction (cont.)

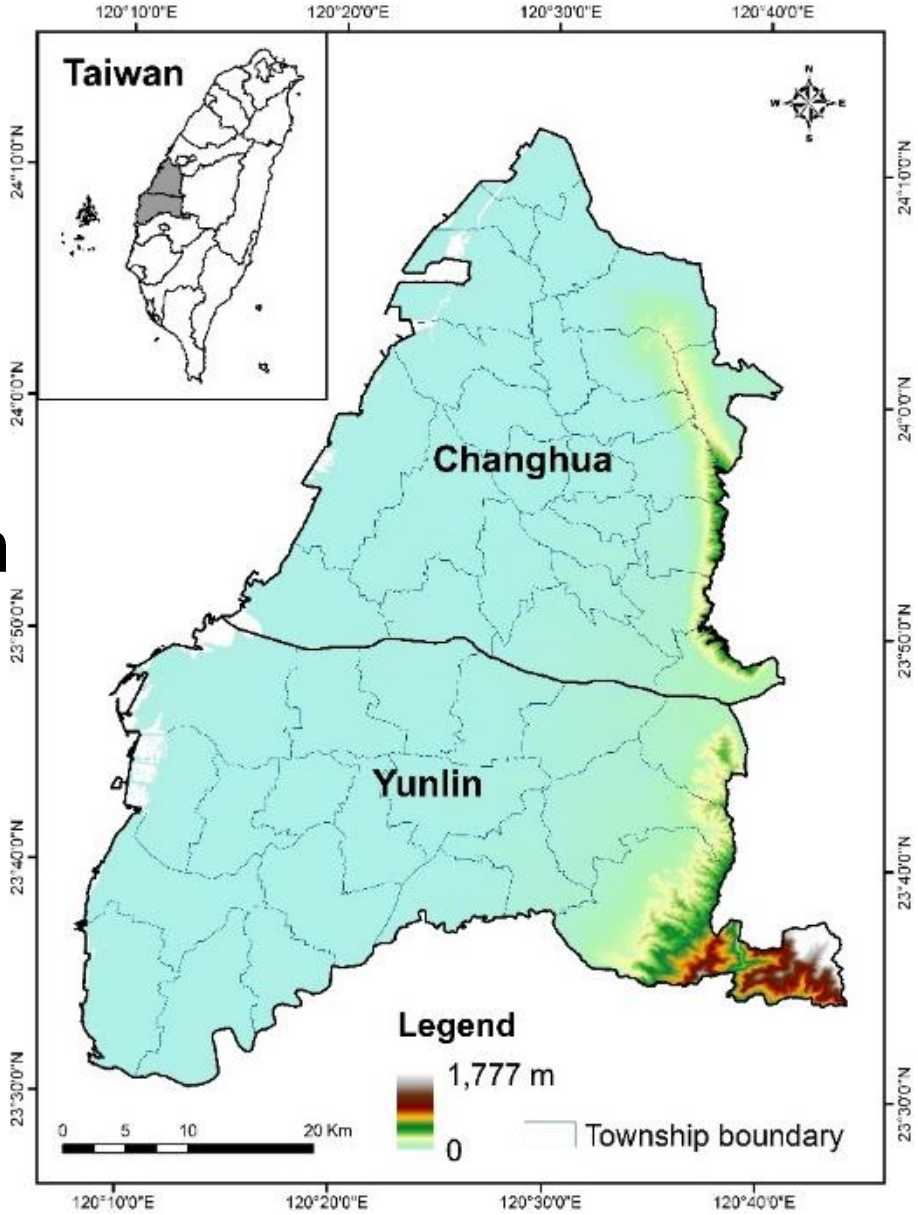
- **Rice fields in Taiwan are generally small (<1 ha) and fragmented.**
- **Rice is yearly monitored due to official initiatives to estimate the harvested area and production.**
- **Rice monitoring has been conducted by costly interpreting aerial photos.**
- **Crop monitoring requires information of crop phenology regarding the spatiotemporal resolution of satellite data.**

# Objectives

- **This study aims to:**
  - **investigate the applicability of MODIS-Sentinel-2 fusion for rice crop mapping.**
  - **estimate rice crop yield (integrating information of remote sensing to improve the accuracy of crop yield model).**

# Study region

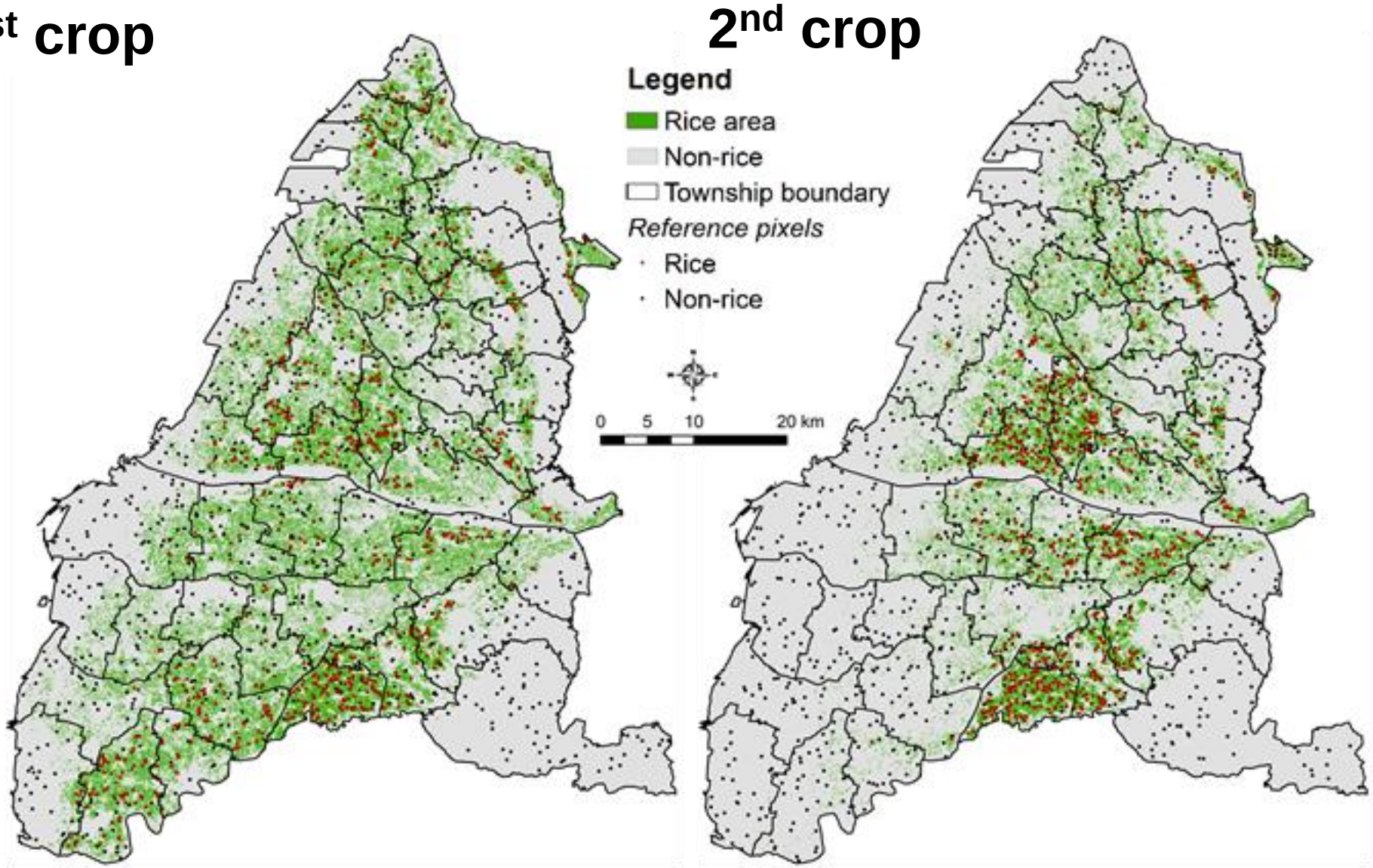
- Study region (3,170 km$^2$) is one of the main rice-producing areas in Taiwan.
- Two cropping seasons:
  - 1$^{st}$ crop: Feb−Mar to Jun − Jul.
  - 2$^{nd}$ crop: Jul−Aug to Nov−Dec.
- Rice varieties: 110−120 days.



# Data for rice mapping

- **MODIS/Terra Surface Reflectance 8-Day L3 Global 250m SIN Grid V006 from Jan to Dec 2017.**
- **Three clear-sky Sentinel-2 images on 15 Feb, 27 Mar, and 5 Jul 2017.**
- **Rice crop maps (scale: 1/5,000) for the 1st and 2nd crops in 2016.**
- **Rice area statistics in 2017 for each township.**

# Ground reference data




*Dots are used for accuracy assessment of the mapping results.*

# Mapping methods

## Data collection

- MODIS data
- Sentinel-1A data
- LULC crop maps
- Rice area statistics

## Data pre-processing

- Geometric correction
- Data fusion (STARFM)
- Construct time-series NDVI
- Noise filtering (EMD)

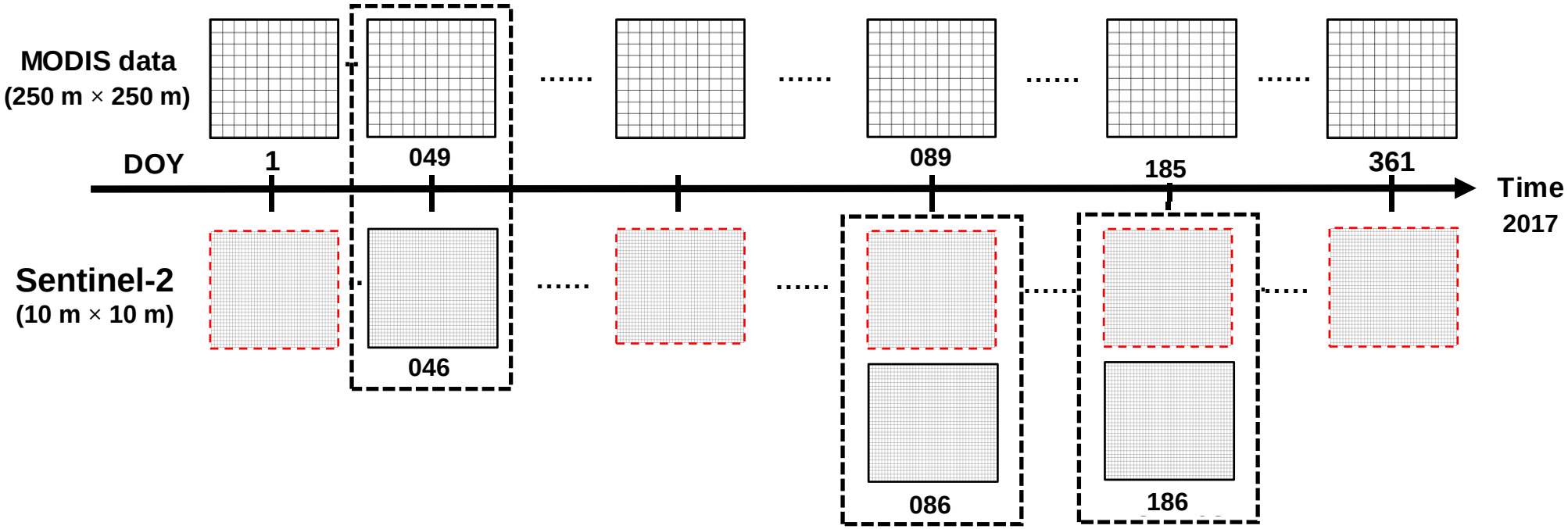
## Rice mapping

- Crop phenology detection
- Rice crop mapping (NDHTI)

## Accuracy assessment

*Normalized difference between transplanting and heading dates (HDHTI)*

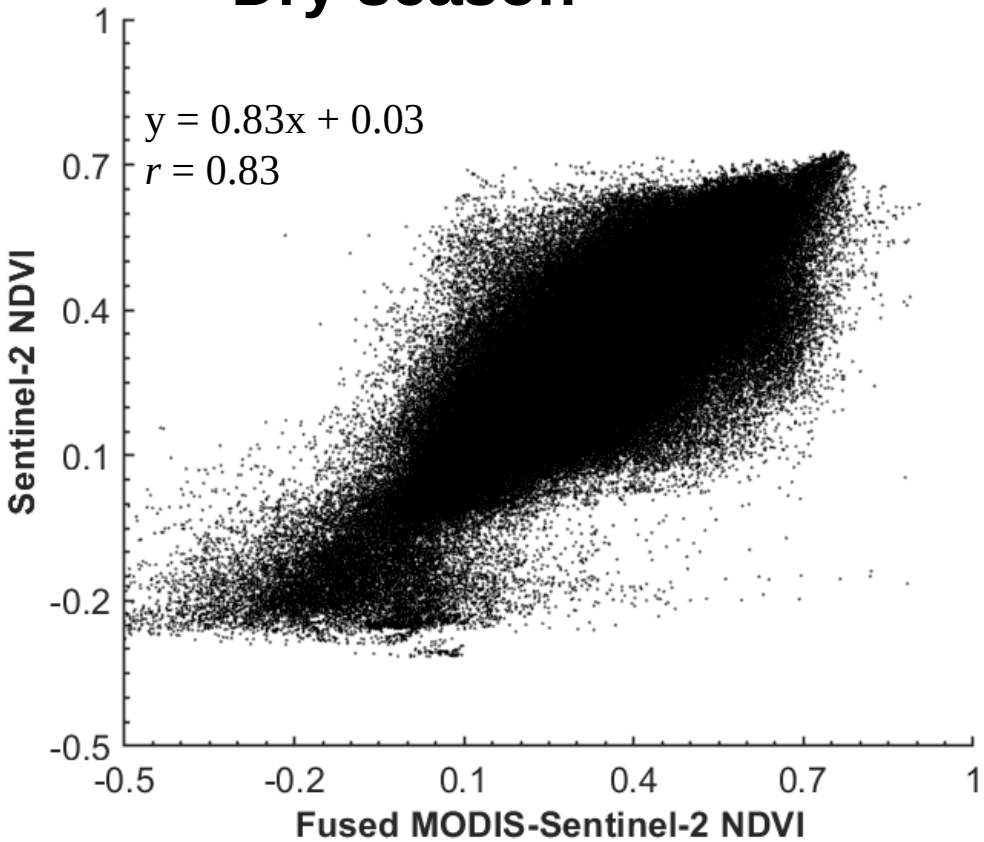
# Data fusion (STARFM)




- 46 MODIS images and a Sentinel-2 image (15 Feb or DOY 046) were used for data fusion.
- Sentinel-2 images (27 Mar and 5 Jul) were used to verify the results of DOY 089 (30 Mar) and 185 (4 Jul).

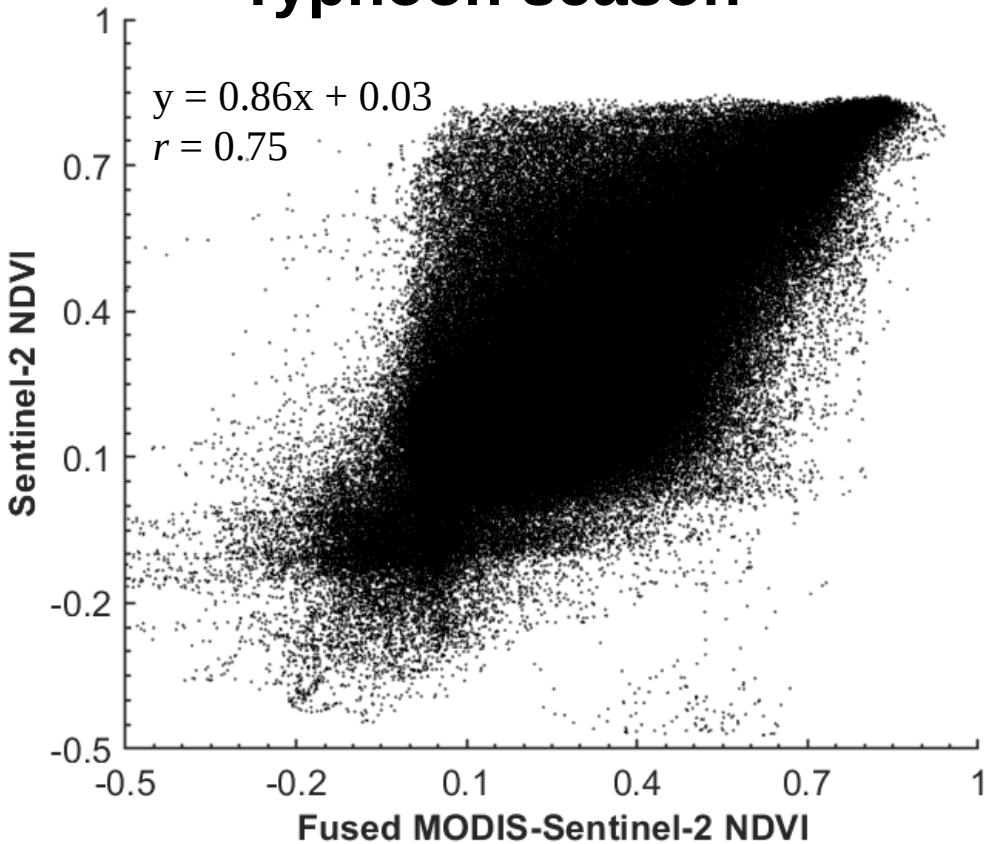
# Correlation analysis

- **Dry season**



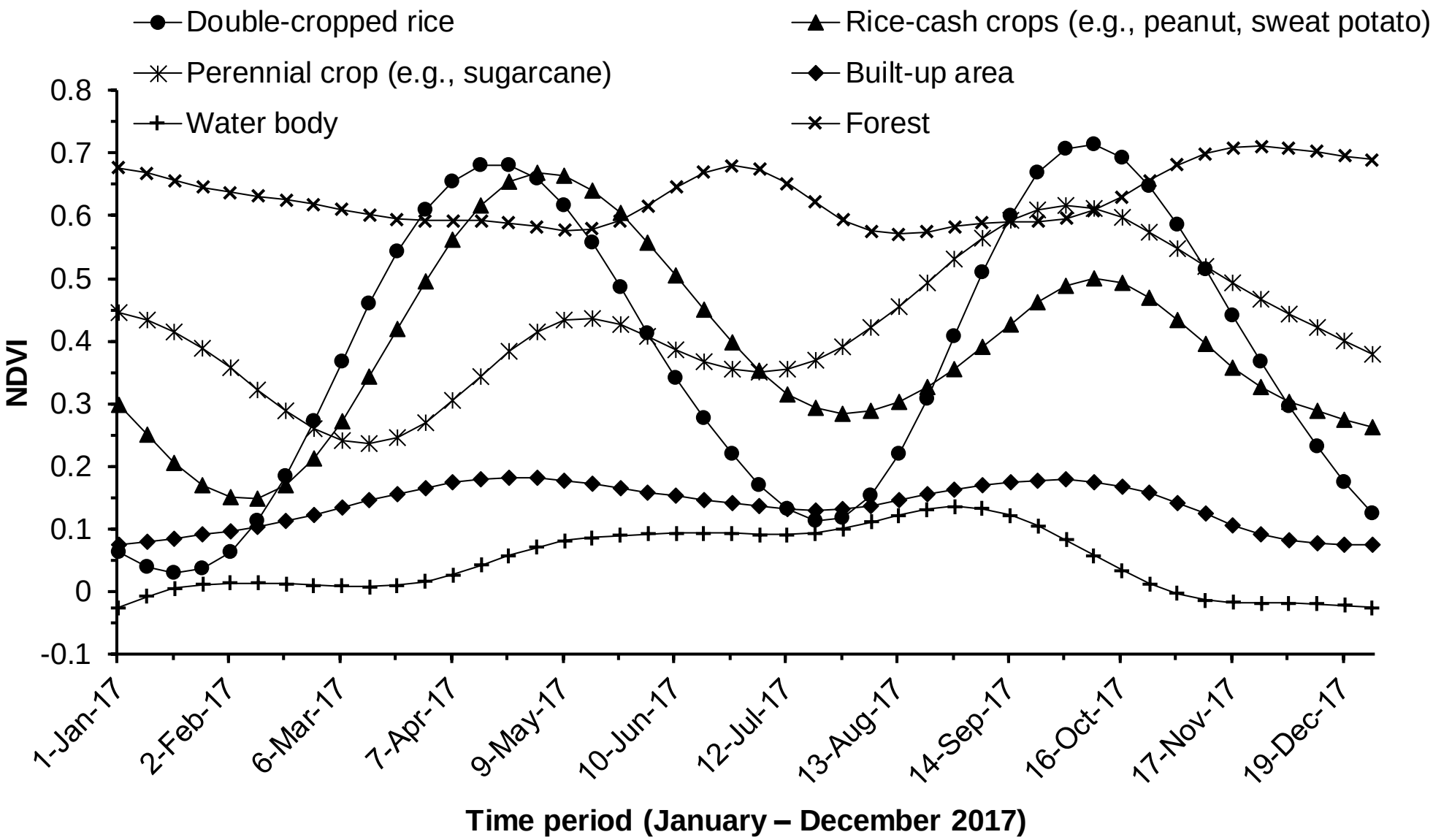

**Fusion data of DOY 089 (30 Mar) and the Sentinel-2 image on DOY 086 (27 Mar).**

- **Typhoon season**

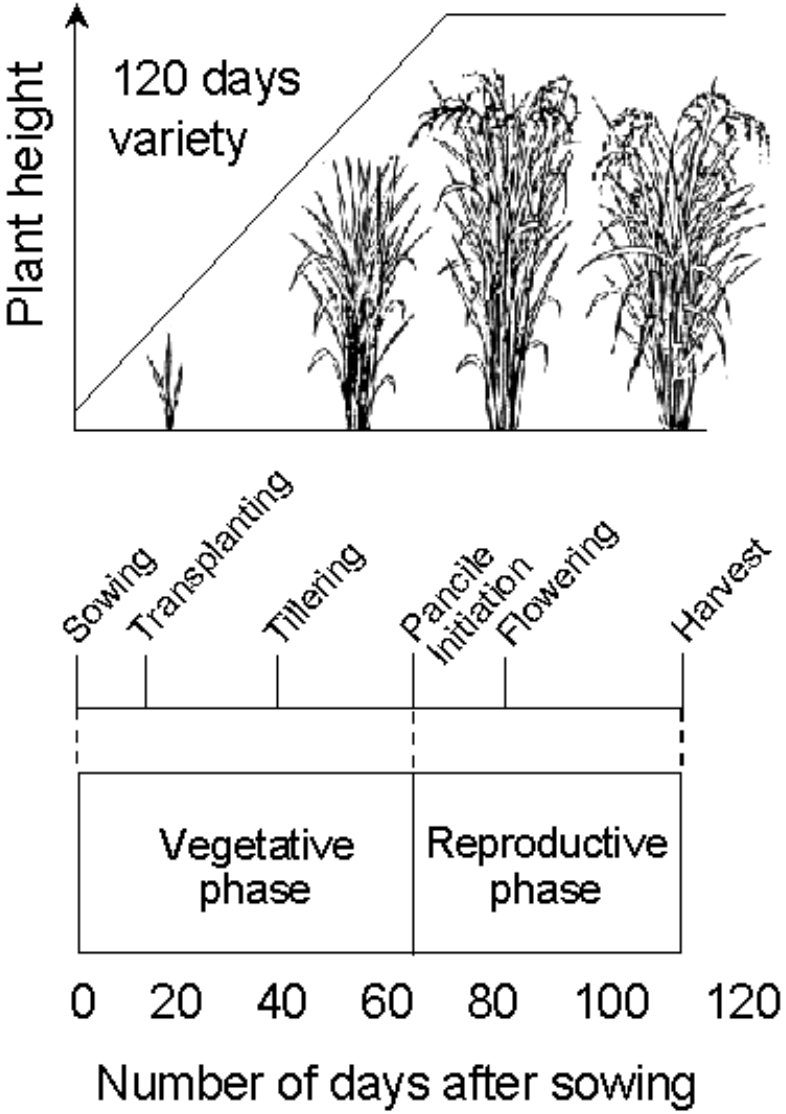



**Fusion data of 185 (4 Jul) and Sentinel-2 image on DOY 186 (5 Jul).**

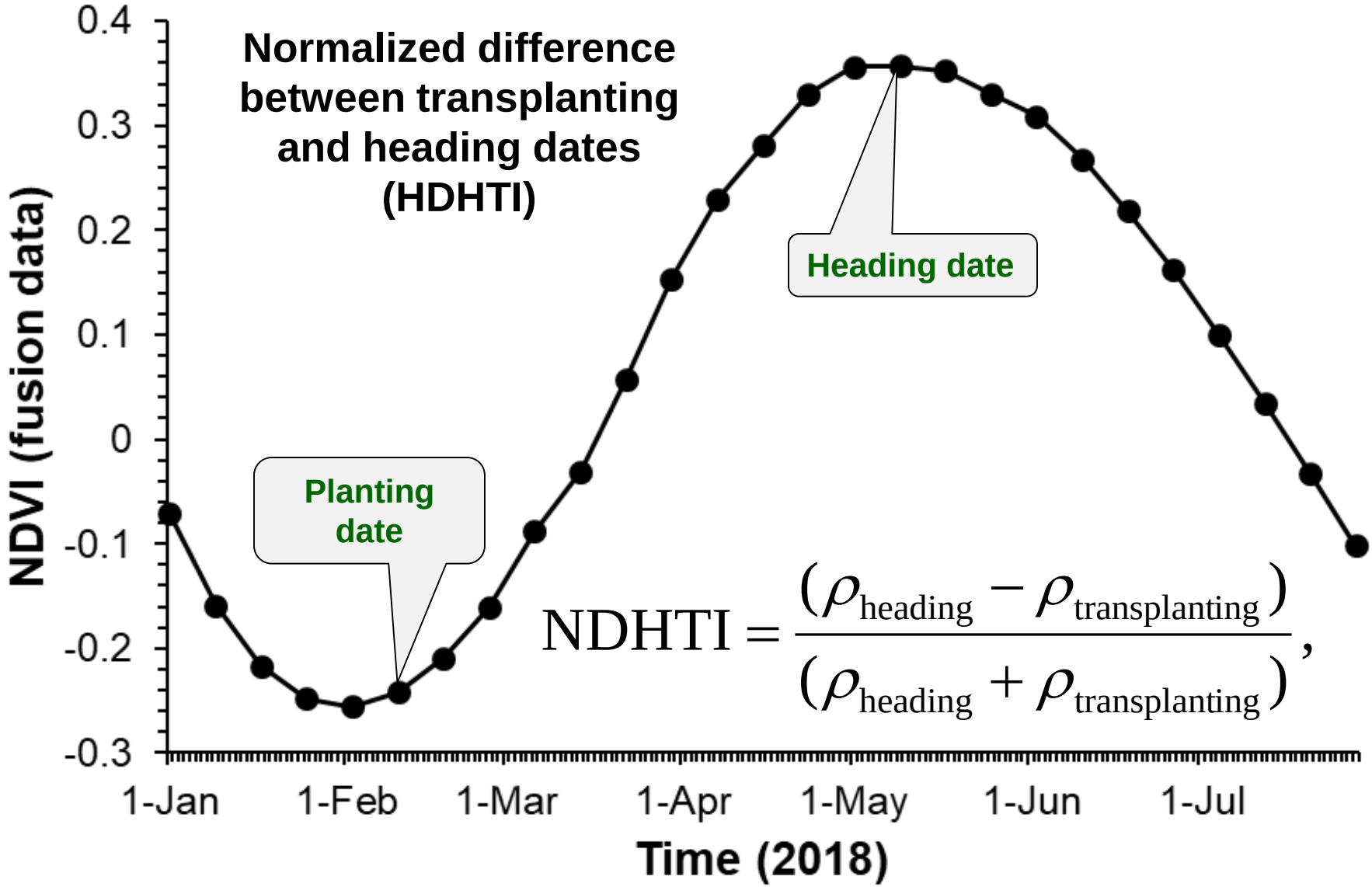
# Smooth NDVI profiles



# Rice growth stages



# Planting and heading dates




$$\mathrm{NDHTI} = \frac{(\rho_{\mathrm{heading}} - \rho_{\mathrm{transplanting}})}{(\rho_{\mathrm{heading}} + \rho_{\mathrm{transplanting}})},$$

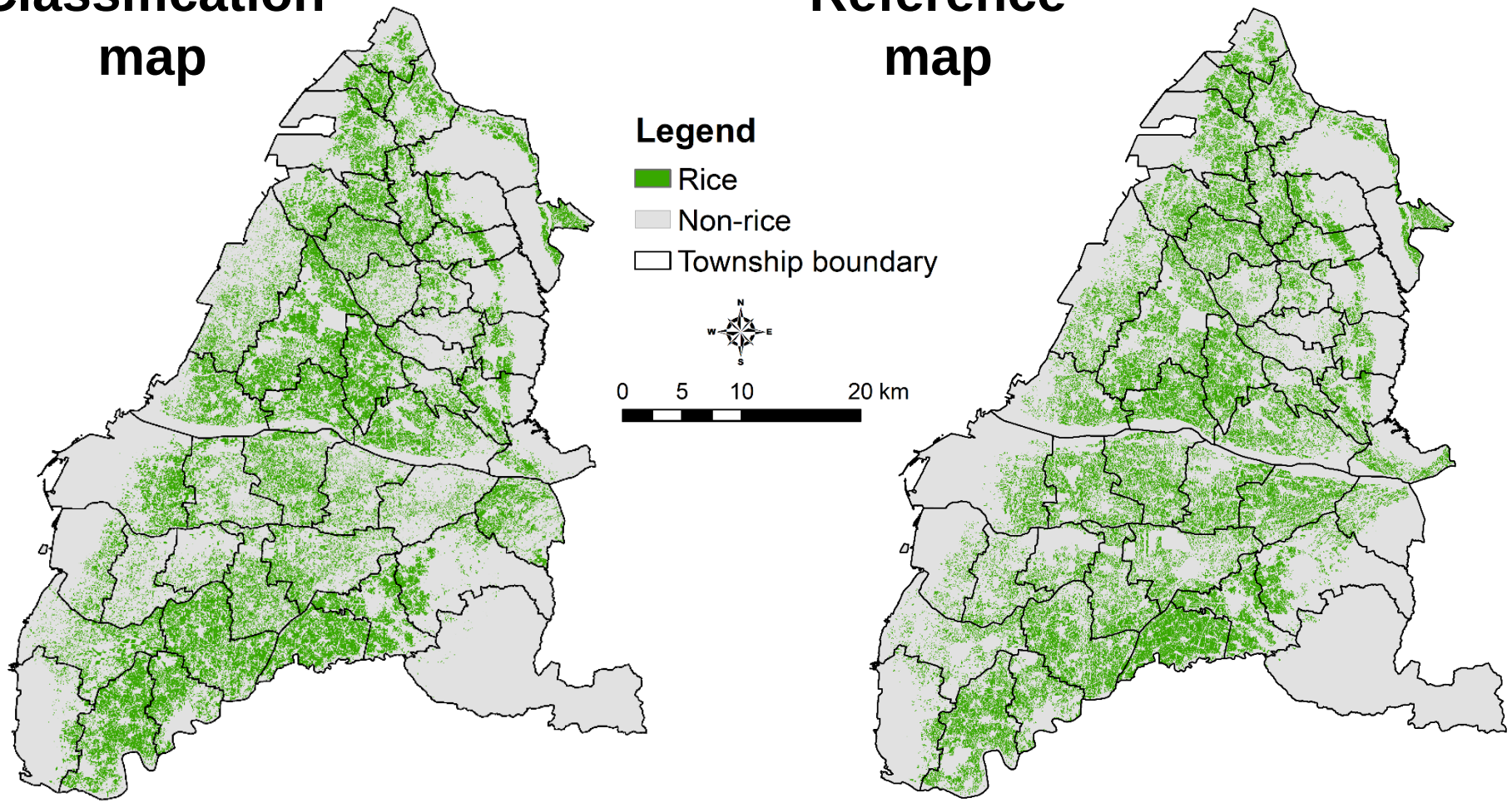
# Rice crop mapping

- NDHTI (0 to 1) indicates a ratio between the difference of NDVI values of transplanting and heading dates.
- 2,000 pixels (1,000 for each class) extracted from the reference data were used for ROC processing to obtain thresholds of 0.38 and 0.49 for the 1$^{st}$ and 2$^{nd}$ crops, respectively.
- The mapping results of the 1$^{st}$ and 2$^{nd}$ crops were verified with the ground reference maps (using 2,000 random pixels), and the government's statistics.

# Results (1st crop)

**Classification map**

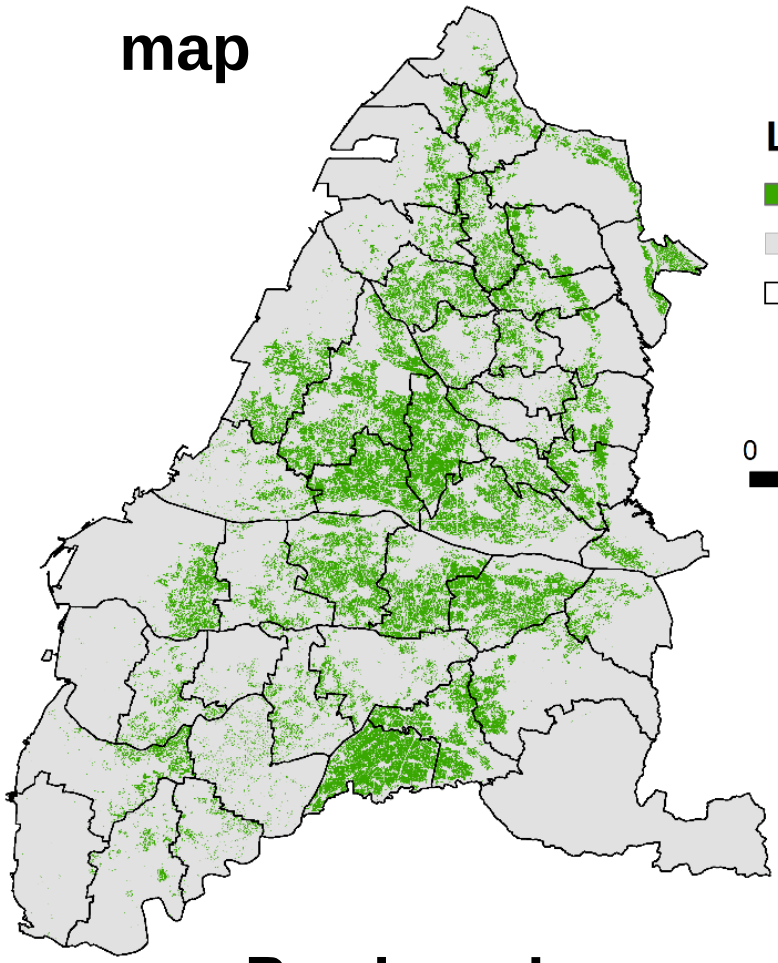
**Reference map**



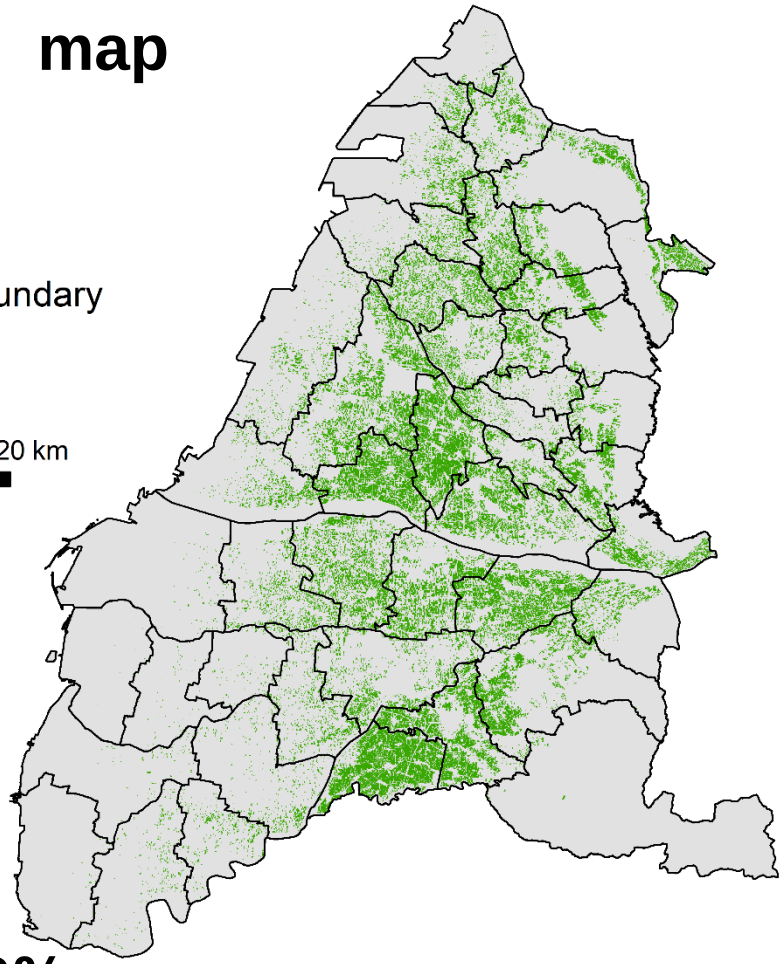

- **Producer's accuracy: 82.7%**
- **User's accuracy: 81.8%**

# Results (2nd crop)

**Classification map**



**Reference map**



**Legend**

- Rice
- Non-rice
- Township boundary

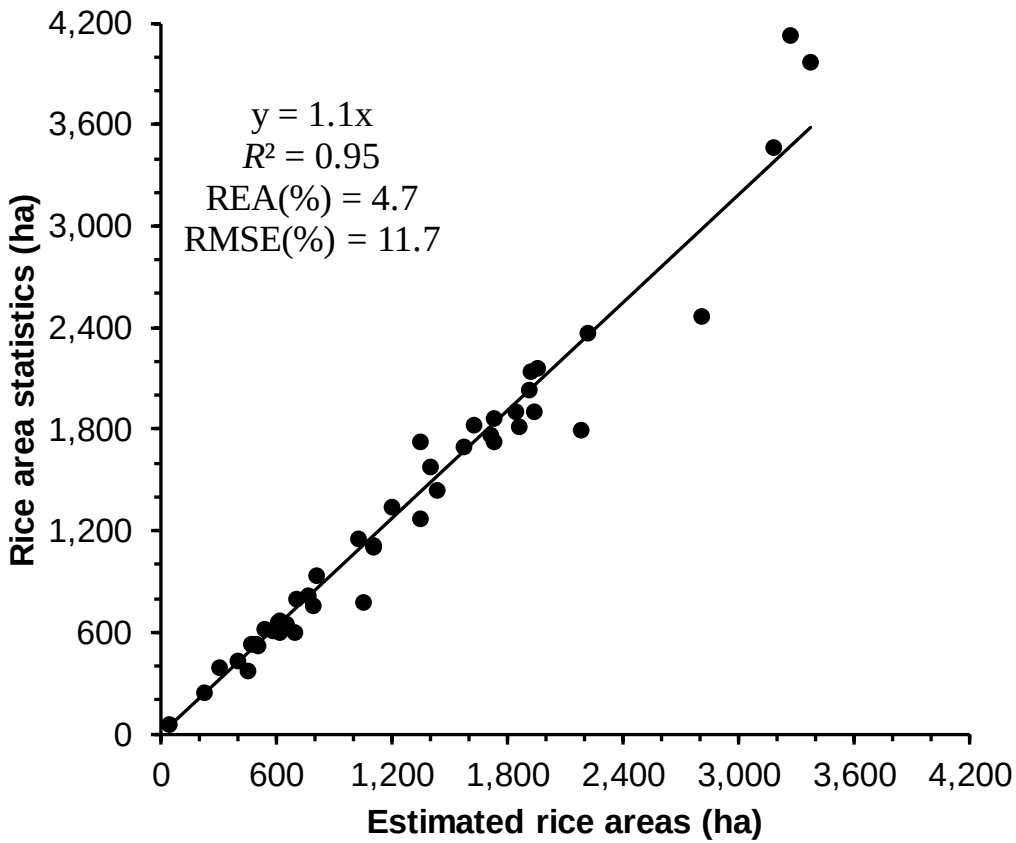
N W E S

0 5 10 20 km

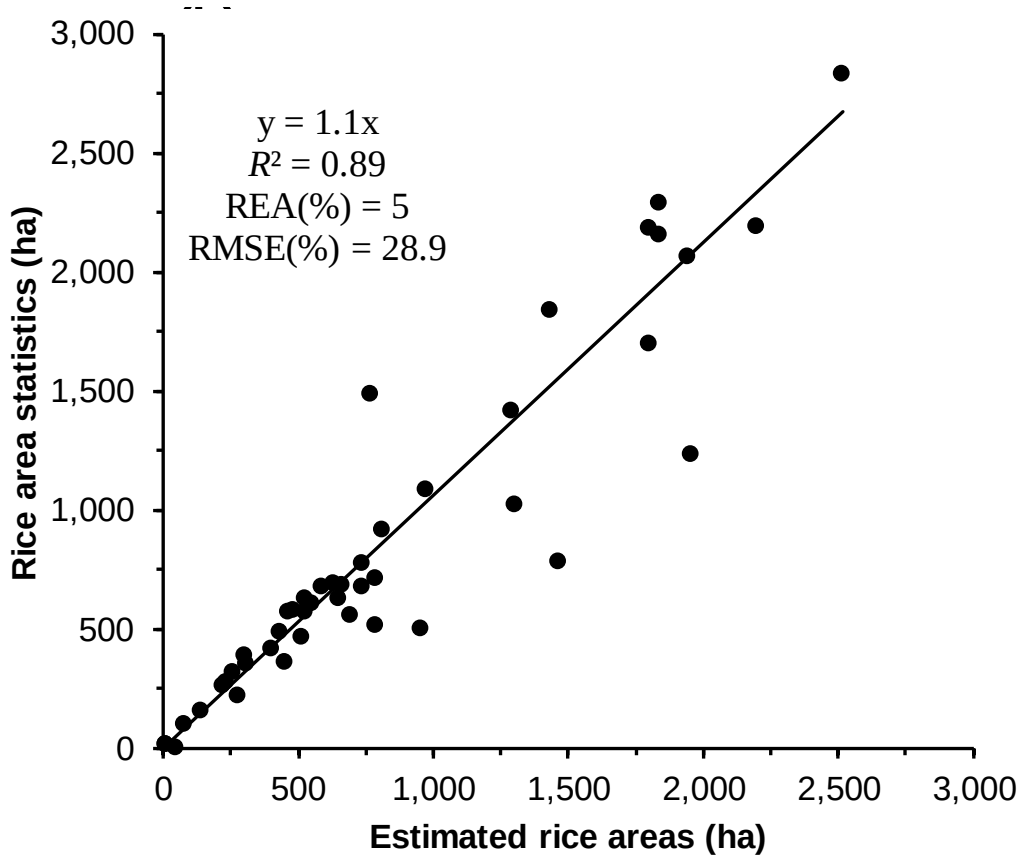
- **Producer's accuracy: 75.8%**
- **User's accuracy: 84.8%**

# Compared with Govt.'s statistics

## 1st crop




## 2nd crop

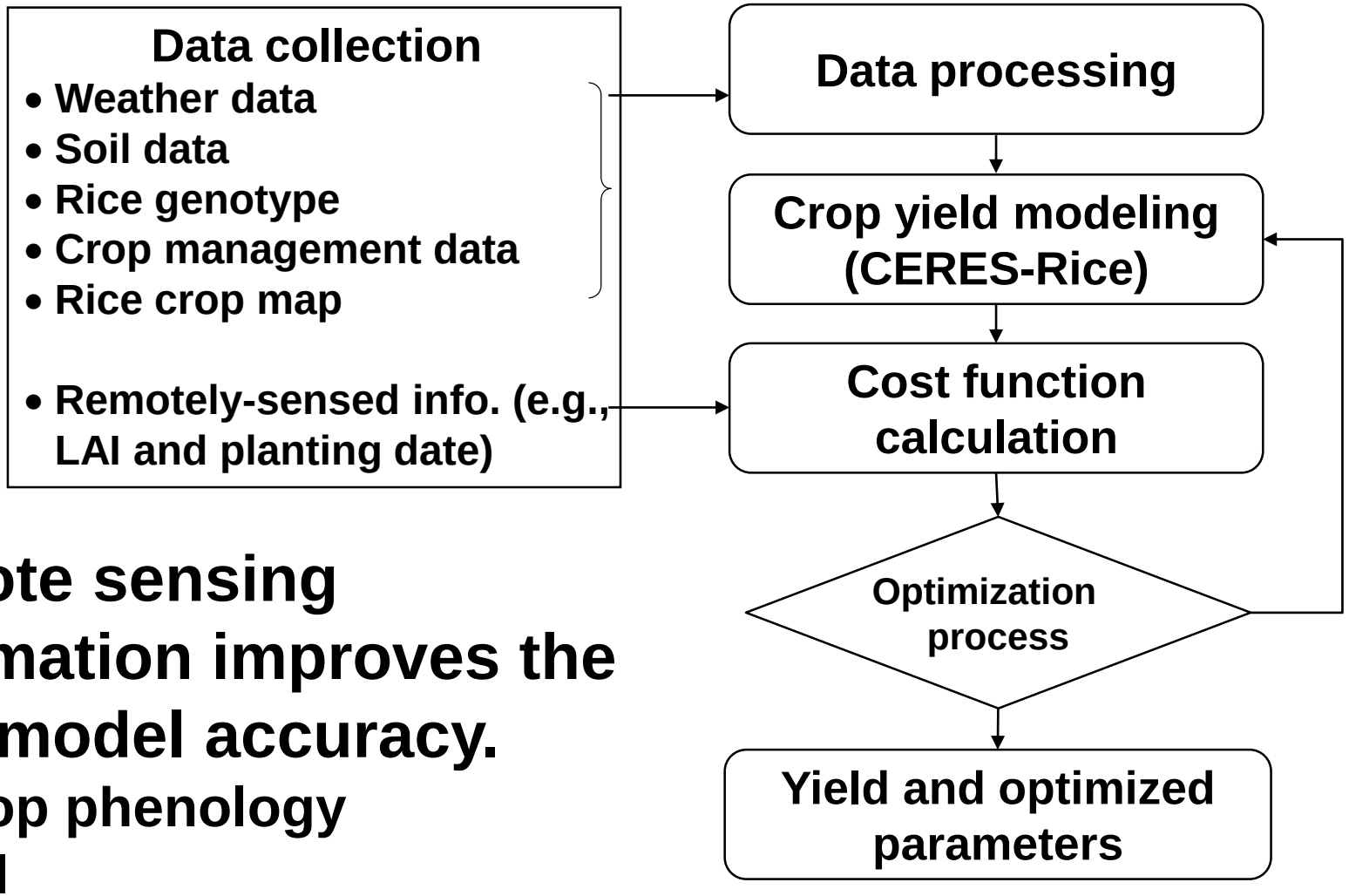



- **Correlation between the mapping results of rice-cropping areas and the government's rice area statistics at the township level.**

# Data for rice yield estimation

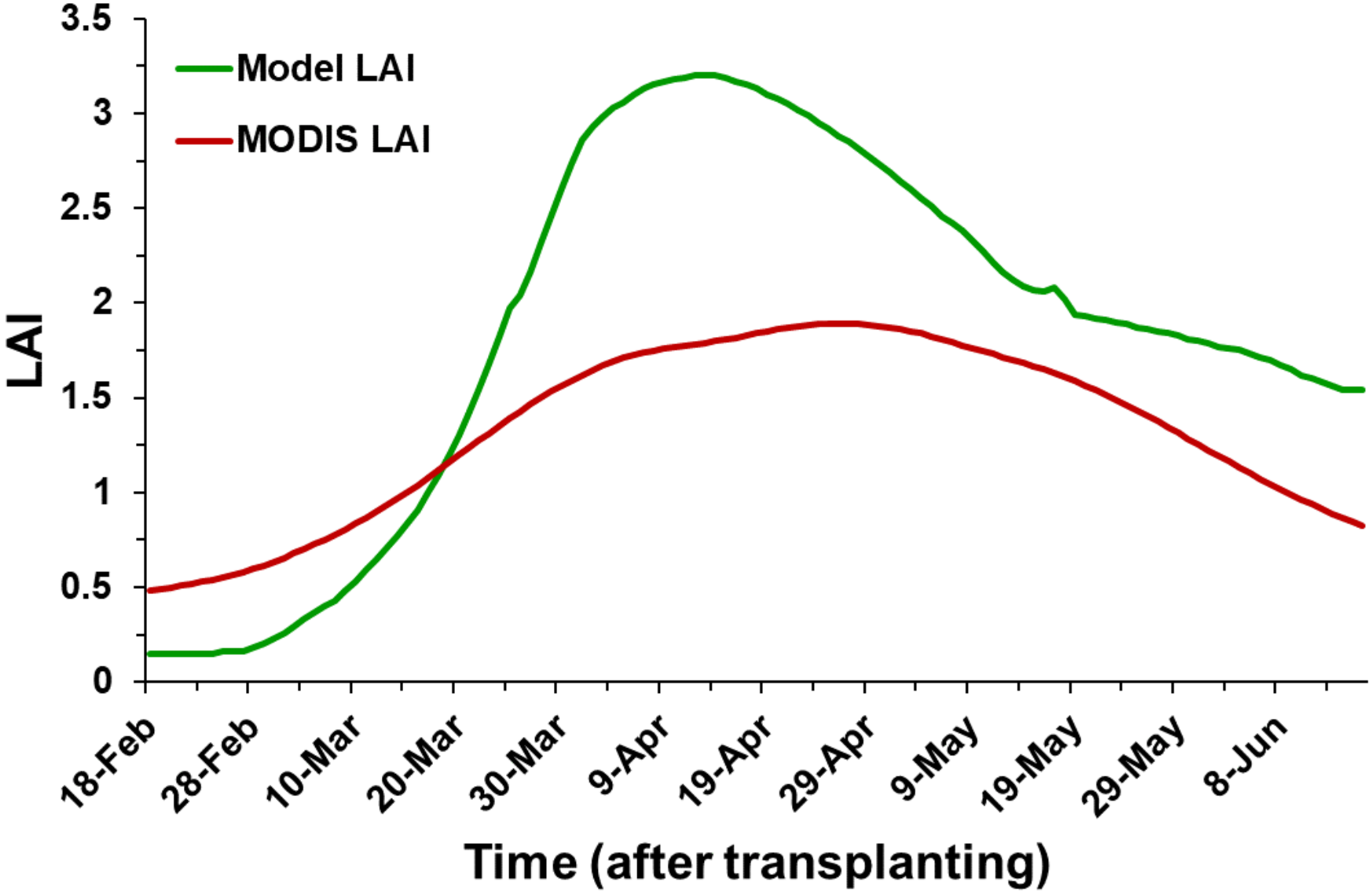
- ***Weather data:*** **daily maximum and minimum temperature, rainfall, and solar radiation.**
- ***Soil data:*** **soil pH, soil organic, carbon, soil texture, coarse fragments, cation exchange capacity, and bulk density.**
- ***Rice genotype*** **and** ***information of crop management*** **(.e.g. fertilizer application, cropping calendar, plant population, transplanting method, and row spacing).**
- **Leaf area index (LAI) from 8-day MODIS data.**
- **Ancillary data (e.g. rice crop maps and rice yield statistics).**

# Yield estimation

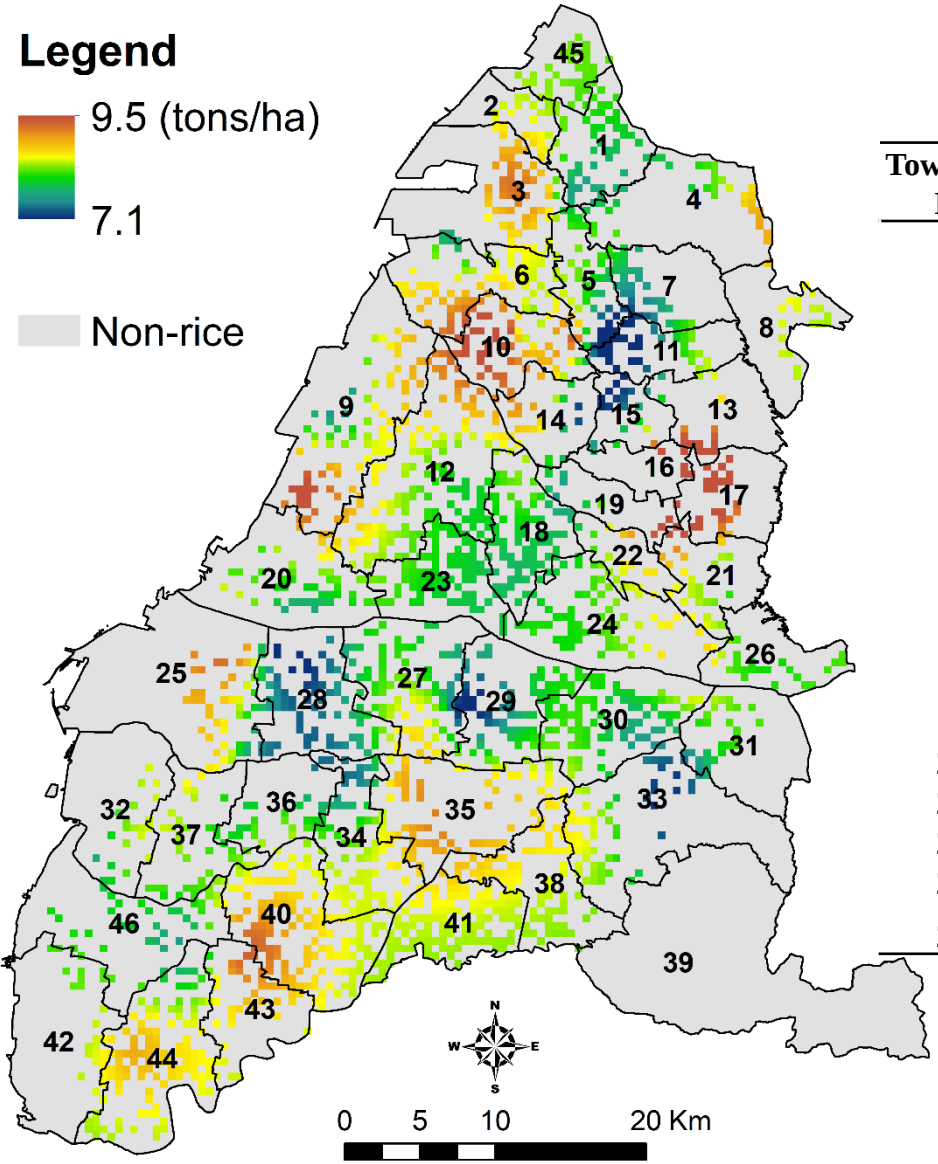



- **Remote sensing information improves the crop model accuracy.**
  - ✓ Crop phenology
  - ✓ LAI

# Preliminary results (1st crop)



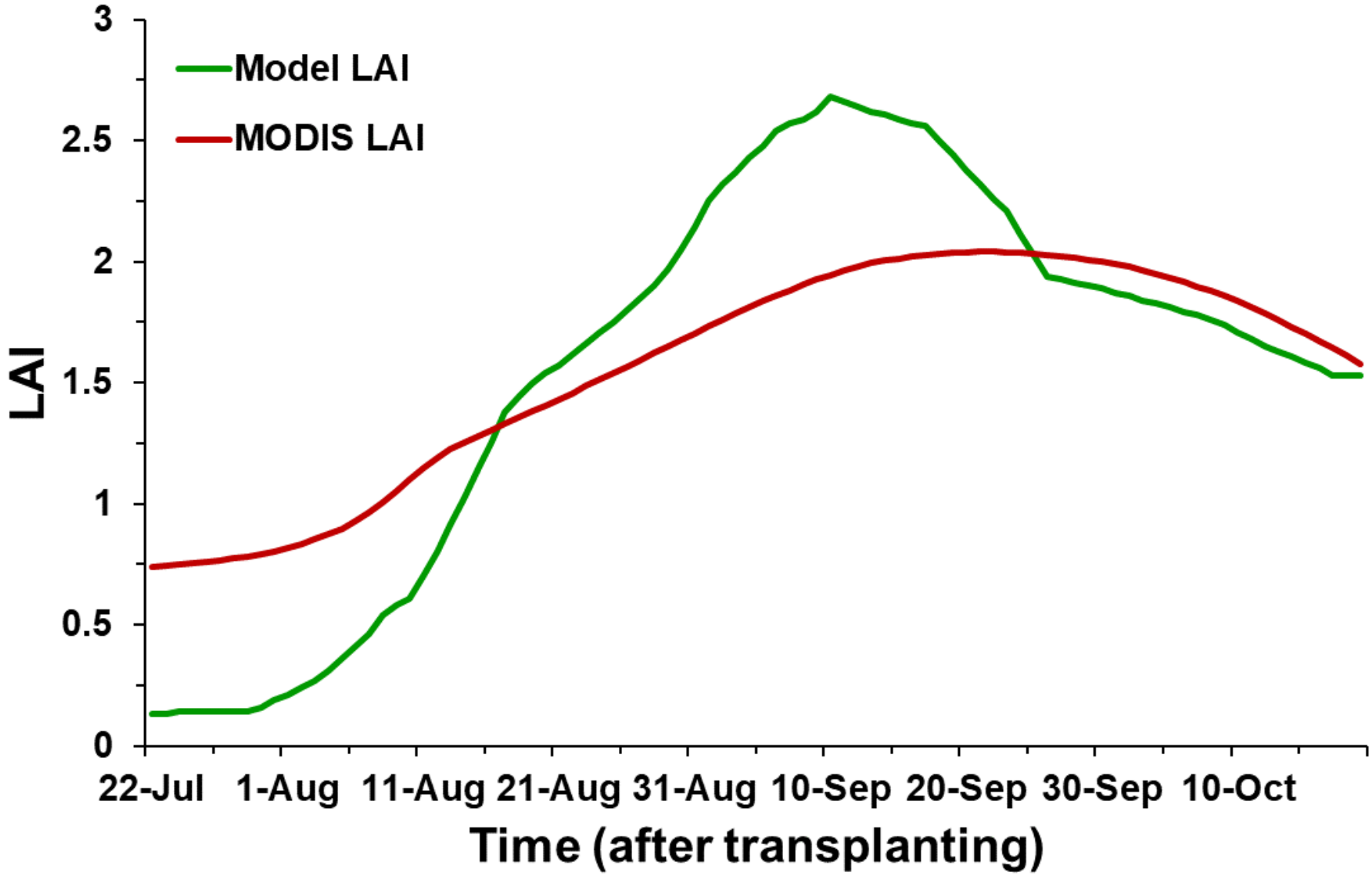
# Preliminary results (1st crop)



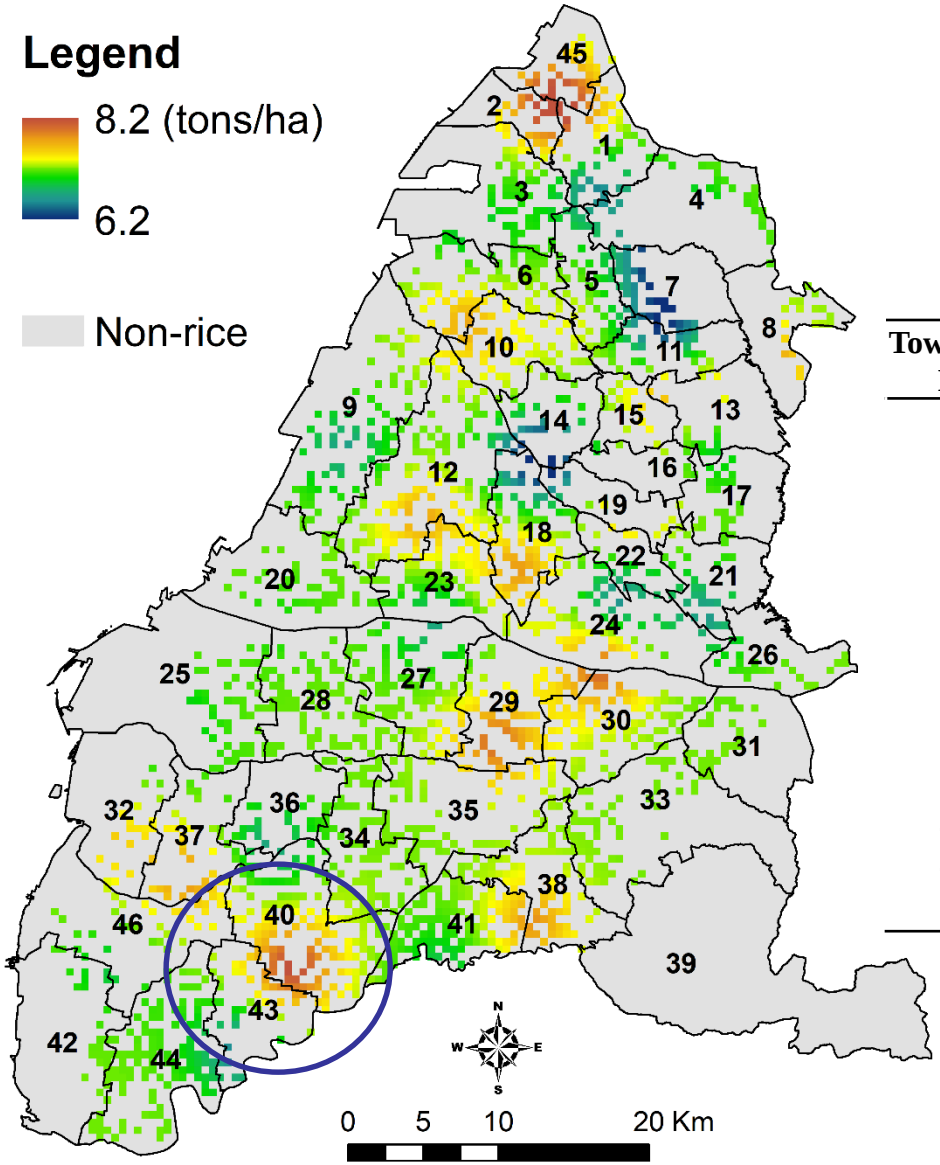

| Township ID | Govt. stat (tons/ha) | Est. yield (tons/ha) | Relative error (%) | Township ID | Govt. stat (tons/ha) | Est. yield (tons/ha) | Relative error (%) |
|---|---|---|---|---|---|---|---|
| **5** | 7.1 | 7.5 | -4.7 | **27** | 7.5 | 7.9 | -4.9 |
| **6** | 8.0 | 7.7 | 3.9 | **28** | 7.4 | 7.4 | 0.7 |
| **7** | 7.5 | 7.6 | -0.9 | **29** | 7.2 | 7.8 | -8.3 |
| **8** | 7.7 | 7.6 | 0.9 | **30** | 7.7 | 7.6 | 1.6 |
| **9** | 7.5 | 7.5 | -0.5 | **31** | 7.3 | 8.0 | -7.6 |
| **10** | 7.0 | 7.6 | -8.2 | **32** | 6.6 | 7.9 | -16.2 |
| **12** | 7.2 | 7.5 | -4.0 | **33** | 6.9 | 8.0 | -12.8 |
| **13** | 7.7 | 7.8 | -0.1 | **34** | 7.3 | 8.0 | -9.5 |
| **14** | 7.4 | 7.7 | -3.7 | **35** | 7.7 | 8.0 | -3.9 |
| **15** | 7.4 | 7.6 | -3.0 | **36** | 7.3 | 7.3 | 0.8 |
| **17** | 7.5 | 7.6 | -0.9 | **38** | 7.4 | 7.9 | -6.3 |
| **18** | 7.6 | 8.2 | -7.0 | **39** | 7.6 | 7.7 | -0.8 |
| **19** | 7.0 | 7.5 | -6.6 | **40** | 8.2 | 8.0 | 2.8 |
| **20** | 7.2 | 7.4 | -2.4 | **41** | 7.3 | 7.9 | -7.6 |
| **21** | 6.9 | 7.5 | -8.2 | **43** | 7.9 | 7.8 | 0.8 |
| **22** | 7.2 | 7.5 | -3.6 | **44** | 7.4 | 7.9 | -5.3 |
| **24** | 7.7 | 7.5 | 1.9 | **46** | 7.3 | 8.0 | -8.1 |
| **26** | 7.8 | 7.5 | 4.1 | | | | |

**RMSE (%) = 6.5**

# Preliminary results (2nd crop)



# Preliminary results (2nd crop)




| Township ID | Govt. stat (tons/ha) | Est. yield (tons/ha) | Relative error (%) | Township ID | Govt. stat (tons/ha) | Est. yield (tons/ha) | Relative error (%) |
|---|---|---|---|---|---|---|---|
| **5** | 7.14 | 6.15 | 16.2 | **22** | 7.22 | 7.05 | 2.4 |
| **6** | 7.98 | 5.01 | 59.2 | **24** | 7.68 | 6.61 | 16.3 |
| **7** | 7.50 | 7.40 | 1.3 | **29** | 7.18 | 7.29 | -1.5 |
| **8** | 7.69 | 5.73 | 34.2 | **31** | 7.35 | 6.19 | 18.8 |
| **9** | 7.47 | 7.43 | 0.6 | **32** | 6.59 | 8.21 | -19.7 |
| **10** | 7.02 | 5.89 | 19.3 | **34** | 7.25 | 6.67 | 8.7 |
| **12** | 7.23 | 7.09 | 2.0 | **36** | 7.31 | 7.25 | 0.8 |
| **13** | 7.74 | 7.85 | -1.4 | **38** | 7.42 | 6.38 | 16.3 |
| **14** | 7.39 | 6.01 | 23.0 | **40** | **8.23** | **5.46** | **50.8** |
| **18** | 7.60 | 5.92 | 28.3 | **41** | 7.30 | 6.32 | 15.4 |
| **20** | 7.22 | 6.80 | 6.3 | **43** | **7.87** | **4.67** | **68.6** |
| **21** | 6.87 | 6.22 | 10.4 | **46** | 7.31 | 6.62 | 10.5 |

**RMSE (%) = 18.1**

# Concluding remarks

- **Information of crop phenology is useful for the rice crop mapping and yield estimation.**
- **The findings confirm the potential application of the mapping approach using MODIS-Sentinel-2 fusion for rice area monitoring.**
- **Although there were still uncertainties attributed to the quality of input parameters, integrating information of remote sensing into the yield model could improve the model accuracy for yield estimation.**

# Thank you!